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The analysis of Lower Limb Muscle Activity and Motion Analysis according to Normal Foot and Flatfoot during Walking

The purpose of this study was to analyze lower limb muscle activity and 3D motion analysis according to change foot arch height during walking. We selected 9 young and healthy people who have been normal foot. And we selected 7 young and healthy people who have been flatfoot. So, people were divided into 2 groups and walked platform during 2 minutes twice for checked by 3D motion analysis. These data were characterized by EMG measurements of three muscles(tibialis anterior, medial and lateral gastrocnemius) while they were walking. The collected data were analyzed by Independent t test using the SPSS statistics program(Ver 12.0). In foot arch change, there were no significant difference in three muscles 3D motion analysis also found that there were no significant difference in joint angles. In this study was to analyze lower limb muscle activity and 3D motion analysis according to change foot arch, but there were no significant difference in 6 muscles neither joint angles.

Key words: *Flatfoot; EMG; 3D Motion Analysis; Foot Arch*

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INTRODUCTION

Different from other animals, humans have foot arch as they walk upright. At the moment, people feel less fatigue in walking only when arch takes proper form as it balances the strength of muscles. Gi et al. suggested that walking is one of essential part of our daily lives as it is within bounds to say that people lead their whole lives walking and it is a basic of all exercise(1). As seen above, walking is a movement that accompanies integrated reflection of numerous skeletal muscles and nerves(2, 3). Due to wrong shoes, posture, and walking in modern days, however, there is gradual increase in illness followed by the deformation in foot arch and its effect on walking pattern. About 5% of all Koreans have flat foot and it is either natural or acquired(4). Flatfoot can be considered as one of the deformations in foot arch. In here, flatfoot refers to the collapse of inner foot arch and clinically it becomes closer to the ground compared to normal(5).

Also, externally, it presents trait such as internal rotation of talus, decrease in height of inner longitudinal arch, and abduction and rotation in forefoot(4). At the moment, there may be a change in the mechanism of movement followed by anatomical change in tarsal bone and it may bring about secondary deformation called degenerative arthritis(6). The balance of body is broken when there is the collapse or deformation in foot arch as it impedes proper walking. While walking, the pronation state that occurs during initial stance phase is delayed or lengthened compared to normal range. At the moment, flatfoot suffers from pain in bumpy road. Also, the weight load is directly passed onto the ground with the difficulty in toe off followed by the weakening of gastrocnemius and soleus(7). As seen above, foot is a organ that secures the stability by balancing the body for the maintenance of upright position of human body. In regards to calf muscles surrounding the ankle, its activity changes all the time according to the position of pendulum structure and state of supporting surface(8). Walking can be defined as an exercise that moves whole body by moving body parts

in stages and maintaining the speed toward certain direction. In here, a walking pattern that represents the diversity in people differs a lot in each individual(9). In order to conduct quantitative analysis on walking, it is necessary to grasp objective walking variables and various methods from simple observation to three dimensional motion analysis based on optical engineering technology are being used(10). Flatfoot patients who experienced the symptoms during general walking has limited means or tools to compensate for the incompetence(11). Various studies on flatfoot are being conducted including the effect of insole type of normal foot and flatfoot while walking or running, difference in sole load between normal foot and flatfoot when performing exercise task(12, 13). In addition, studies such as the distribution of sole pressure while walking or influence of shoes with curved soles on the change in static posture and EMG of calf are continuously being conducted as the emphasis is put on the form of walking nowadays(8, 14). In preceding studies, ankle joint was measured in accordance with the plan by dividing the walking cycle. In regards to the muscle activity, the difference in activation was also compared in accordance with walking cycle. As a result, the activation of tibialis anterior muscle was presented to be high in flatfoot group from initial to middle stance phase and other muscles presented weak muscle activity compared to it. Also, flatfoot group displayed bigger ankle movement in plantar flexors compared to normal group in toe off and it displayed significant difference(11). However, it has a limitation that only difference in movement from knee joint and ankle joint can be presented.

Therefore, the purpose of this study lies in analyzing the movement in joint facet of lower limb and examining the difference in muscle activity of lower limb based on the change in height of foot arch subjecting normal foot and flatfoot. In other words, the difference between groups regarding each joint in lower limb and difference in the degree of rotation in pelvis while walking were measured.

METHODS

Subjects

The subjects of this study is 20 students in 20's who are attending N university located in Cheonan-si. Although number of subjects for both normal group and flatfoot groups was 10, 1 subject in normal groups and 3 subjects in flat foot group dropped out during the experiment due to personal reasons. Therefore, total 16 subjects including 9 subjects in normal group and 7 subjects in flat foot group participated in this experiment. They have listened to the explanation on the experiment process, had no problem performing the experiment, and had voluntarily agreed to participate in the experiment. Also, random selection was carried out from those who do not have skeletal muscular disease in lower limb and those who received surgical operation due to the injury or lesion in lower limb were excluded.

Measurement

Measurement tool

Experiment equipment used in this study is as following(Table 1).

Table 1. Measurement tool

Name of equipment	Product name	Manufacturer
EMG	Pocket EMG	Italy/ BTS
Motion capture	Smart-E	Italy/ BTS
Electronic scale	150A	Korea/ CAS

Procedure

Foot type

Form of foot arch was looked into by printing foot stamp and examining through foot printer. 20 subjects who participated in the experiment gently placed right and bare foot on the foot printer and they lifted their feet after staying for 3 seconds after exerting full weight(15). Foot print interpretation method using foot printer is as following(Fig 1).

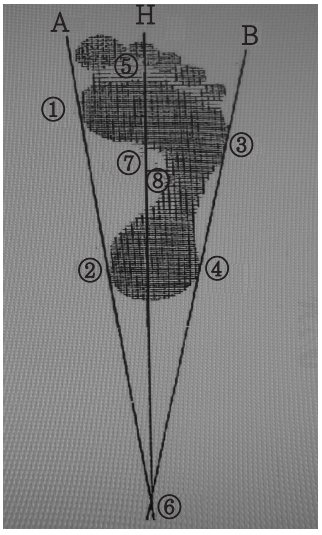

Fig. 1. Interpreting manners of sole print

① The far left outside point of first metatarsal head
② The far left outside point of calcaneus
③ The far right outside point of 5th metatarsal head
④ The far right outside point of calcaneus
⑤ The center of balance of 2nd toe
⑥ The crossing of line A and line B
- line A: the direct line, linking ① and ②
- line B: the direct line, linking ③ and ④
- line H: the direct line, linking ⑤ and ⑥

⑦ The longitudinal length of foot arch
⑧ The transverse length of foot arch
If the foot arch is located in the part of HA, it is a normal foot and if located in the part of HB, it is a flat foot. When there is no shape of foot arch, it is a pes cavus foot(high arch foot).

Analysis on walking pattern using motion capture

In order to numerically measure walking pattern in regards to the change in height of foot arch of experimentee, it was measured using three dimensional motion capture. Chief researcher attached the marker of motion capture to anterior superior iliac spine, hip joint, knee joint, lateral epicondyle of foot, and fifth metatarsal bone of both sides. Motions were measured in three dimension regarding markers attached to each joint facet. Data regarding the angle of hip joint, knee joint, and ankle joint while walking and the size of motion when pelvis is rotating toward left and right(x axis and y axis) were examined. Angle of hip joint was measured based on the attachment on anterior superior iliac spine and knee joint facet in same side, angle of knee joint was based on the attachment on hip joint facet and lateral epicondyle of foot, and angle of ankle joint was measured based on the attachment on knee joint facet and joint facet of fifth metatarsal bone. In regards to the rotation of pelvis, a virtual point that is in same straight line as sacrum was taken as the standard and the distance anterior superior iliac spine moved toward x axis and y axis from that point was measured. Then, the difference between two groups were examined. Under the supervision of two specialists, the location of a virtual point was set. Also, angle of all joints was measured based on a single walking cycle. In order to exclude intentional walking, the experiment was conducted without informing the experimentee about the time of measurement and mean data was acquired by measuring twice per each person.

Measurement of electromyogram using EMG

In order to examine the difference in the activity of low limb muscles while walking between two groups, pocket EMG was used. In order to minimize the error in experiment, experimentee wore shorts. For the parts to attach electrode, the removal of hair and sterilization were carried out. At the moment, electrode was continuously attached by the chief researcher for the unity. Lateral gastrocnemius, medial, and tibialis anterior were taken as subjects that have influence on walking. An electrode was attached to the belly of each muscle.

Data Analysis

Physical traits of 16 experiment participants were analyzed with descriptive statistics using SPSS(Ver 12.0) in this study. Muscle activity of normal group and flatfoot group and mean and standard deviation in accordance with the difference in joint angle while walking was calculated. Then, normal distribution was confirmed through K-S test. Comparative analysis on the difference in angle and muscle activity of each joint was carried out with independent t-test and all statistical significance level was set as .05 in this experiment.

RESULTS

General Characteristics of the Subjects

The characteristics of the subjects are listed in Table 2.

Table 2. General characteristics of the subjects

(Mean±SD)

Physical traits	Normal foot(n=9)	Flatfoot(n=7)	p
Height(cm)	172.22±9.40	168.57±8.00	.426
Weight(kg)	58.44±6.46	60.00±8.50	.683
Age(yrs)	22.44±2.19	22.14±1.77	.771
Foot size(mm)	256.11±12.94	252.14±11.13	.529

Comparison on Muscle Activity of Left · Right Side of Three Muscles Based on Foot Type

There was no significant difference in lateral and medial gastrocnemius, tibialis anterior based on normal foot and flatfoot ($p>.05$)(Table 3).

Table 3. Comparison on muscle activity of 6 muscles based on group (mV)

Muscle	Normal foot	Flatfoot	t	p
	Mean±SD	Mean±SD		
Right lateral gastrocnemius	.044±.025	.025±.009	2.110	.059
Left lateral gastrocnemius	.034±.012	.028±.010	1.078	.299
Right medial gastrocnemius	.061±.028	.060±.023	.125	.902
Left medial gastrocnemius	.089±.069	.065±.028	.938	.368
Right tibialis anterior	.052±.014	.043±.023	.859	.411
Left tibialis anterior	.050±.015	.056±.029	−.496	.633

Comparison on Angle of Left · Right Ankle Based on Foot Type

There was no significant difference in angle of hip, knee, and ankle joint while walking based on normal foot and flatfoot($p>.05$)(Table 4).

Table 4. Comparison on angle of each joint between group (Degree)

Joint	Normal foot	Flatfoot	t	p
	Mean±SD	Mean±SD		
Right hip joint	126.94±22.05	115.31±25.30	.964	.354
Left hip joint	127.63±15.82	127.95±19.80	−.035	.972
Right knee joint	32.77±11.49	27.31±14.59	.814	.433
Left knee joint	20.18±8.88	24.52±8.35	−1.003	.334
Right ankle joint	93.11±11.13	92.86±4.89	.061	.952
Left ankle joint	90.50±10.48	87.23±7.59	.724	.481

Comparison on Difference in Motion of Pelvis

There was no significant difference in motion regarding left and right of pelvis based on normal foot and flatfoot($p>.05$)(Table 5).

Table 5. Comparison on difference in motion of pelvis (mm)

	Normal foot	Flatfoot	t	p
	Mean±SD	Mean±SD		
From x axis	807.12±484.09	688.36±440.70	.512	.617
From y axis	8.36±3.10	8.19±4.45	.084	.935

DISCUSSION

The purpose of this study was to compare the muscle activity of lower limb muscle(tibialis anterior, medial and lateral gastrocnemius) followed by the collapse of foot arch and the angle of each joint while walking in order to examine the change in the muscle activity of lower limb and walking pattern based on the change in the height of foot arch. As a result of comparing the muscle activity while walking between normal foot group and flatfoot group with the collapse of foot arch in accordance with the height of foot arch, there was no significant difference in all of three muscles(tibialis anterior, medial and lateral gastrocnemius). However, it may be different whether or not to select people who have experienced the symptoms of skeletal muscular disease as experiment subject. Subject may not have experienced skeletal muscular disease as there is the difference in degree even through subject may physically belong to flatfoot group(5). In addition, Chung et al. suggested that there is correlation between the collapse of foot arch and experience of symptom although many flatfoot patients complain about the pain after strenuous work(6). Therefore, it can be considered that no evident significance has been found as there are subjects who do not have difficulty in daily lives regardless of having flatfoot. In the study of Kim the correlation between age, weight, height, height of heel, change in shoe size, and occupation of normal group and flat foot group was examined(15). As a result, there was significant difference in that there are more flatfoot with the increase in age. Although there was a change in height of foot arch followed by physiological change caused by aging of tissue, muscle and others with the increase of age, there was no difference relevant to physiological aging as the subject of this study was in their 20's. Although there was no statistically significant difference in preceding studies, other variables presented significant trend thus in depth study on flatfoot group seems to be necessary. As a result of looking into the difference in the trait of physical strength between normal foot and flatfoot in the study of Sun et al., there also was not significant difference in regards to the muscle strength of knee(16). This study also taken subject who did not experience skeletal muscular symptom and this is believed to be the reason why there was no statistical difference. In study of Kim et al. as a result of analyzing the change in the range of joint motion for each walking cycle with the use of three dimensional motion capture, mean joint motion angle for hip joint was smaller in normal foot group compared to flatfoot group and that of knee joint and ankle joint was bigger in normal foot group compared to flatfoot group in initial stance phase(17). Although it did not display statistically significant difference, there was a difference in angle based on the change in height of foot arch thus it presented result different from this study. Although this study was carried out subjecting certain age group that is 20's, as a result of analyzing the change in the angle of each joint that differs during normal walking with the increase of age by measuring the walking of various age groups in the study of Chung et al. and others, significant difference was confirmed as there was the increase in the bending of hip joint and knee joint in stance phase(18). In the future study, analysis on the walking of flatfoot based on age shall be carried out. This study has a limitation for generalization as there were only 16 subjects and walking was performed in small space that was lab. Also, although there are various variables in walking, the experiment was conducted only on muscle and joint among them. In the future, studies on the difference in muscle activity between flexible flatfoot and rigid flatfoot shall be carried out. Also, one of typical traits of flatfoot is the rotation of supporting surface of heel bone toward outside caused by the weight support line of leg and it is called as valgus(19). Therefore, the study on the deformation of valgus and varus followed by the collapse of foot arch or the study on walking posture shall be carried out.

CONCLUSION

The purpose of this study was to examine the difference in the muscle activity of lower limb and angle of each joint in accordance with the height of foot arch by requesting normal foot and flatfoot students of N university in their 20's to walk certain distance. There was no significant difference as a result of comparing muscle activity of six muscles in accordance with the height of foot arch. Also, there was no significant difference in the angle of lower limb examined through motion capture. The result different from preceding studies came out due to the fact subject was flatfoot who did not experience skeletal muscular disease, walking in small lab is different from actual walking, and there was only small number of experimentee that was 16. As this study has various limitations, future studies regarding such limitations shall be carried out.

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